



SmartCitiesWorld
White paper

Buildings are getting smarter: are they also getting healthier?

How human-centric design is improving well-being in commercial buildings

In association with

 **signify**

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SmartCitiesWorld Trend Reports examine an emerging or growing trend in smart cities, highlighting progress so far and future potential, as well as spotlighting case studies from cities around the world.

In this report, we examine how connected lighting can lead to a more efficient workplace and healthier workforce.

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Building a healthier worker

When buildings get smarter, cities get smarter. At least that is the premise of smart city leaders and building developers. Innovative developers construct smart buildings so that systems are integrated and connected. Smart building design – based on IoT connectivity, sensor platforms, network technology and cloud computing – render buildings more intelligent and sustainable and contribute to the appeal of smart cities. What about the well-being of a building's occupants? Does a smarter building automatically deliver a higher level of well-being?

Employee well-being is a key factor in promoting job performance, personal health, productivity and creative thinking while alleviating absenteeism and presenteeism. These are among the findings of research on how buildings affect the people who work in them. Because labour costs can reach an estimated 70 per cent of total business costs – and executives are increasingly concerned about attracting, engaging and retaining top talent – it makes sense for organisations to be concerned about well-being. Smart buildings designed with people in mind are essential to create the conditions for employee well-being.

How to ensure a building contributes to well-being is a challenge for architects, designers, real estate developers and building owners – and for smart city leaders striving to improve the quality of urban life and health. In this paper, we explore trends in smart buildings and how innovative lighting solutions open windows of opportunity to improve employee well-being.



What do we mean by employee well-being?

“There is no consensus around a single definition of well-being,” says the United States Centers for Disease Control and Prevention (CDC), but there is “general agreement that well-being includes the presence of positive emotions and moods, the absence of negative emotions, satisfaction with life, fulfilment and positive functioning”. Studies reveal that well-being is associated with:

- Self-perceived health
- Healthy behaviours
- Mental and physical health
- Social connectedness
- Productivity
- Factors in the physical and social environment
- Longevity

The World Health Organisation (WHO) defines health as “a state of complete physical, mental and social well-being”. The multiple dimensions of health are represented by indicators such as general health, subjective well-being, chronic illness, absenteeism and presenteeism.

Absenteeism includes intentional or habitual absence from work. Excessive absences lead to lower productivity. A survey by the Gallup-Sharecare Well-Being Index indicates the total annual costs related to lost productivity exceeded \$80 billion for the 77 per cent of workers who fit the definition of having a chronic health condition. Investopedia defines presenteeism “as the problem of employees who are not fully functioning in the workplace because of an illness, injury or other condition.” Based on a study quoted in Forbes, presenteeism costs the U.S. economy more than \$150 billion each year.

In the context of smart buildings, well-being is about ensuring a healthy and comfortable place for employees to work, interact, innovate and be productive, while reducing absenteeism and presenteeism. It is about providing a flexible approach to managing the indoor environment and workspace. Flexibility is vital because each building is unique and each building occupant has unique preferences. “As I see it, well-being was not normally at the forefront of architects’ and contractors’ minds. But developers and building owners have since recognised that well-being is crucial,” said Malcolm Anson, president of the Building Controls Industry Association (BCIA), in *Smart Buildings Magazine*. “Buildings are expected to be intelligent and that means adapting to the needs of occupants”. In the near future, it also means adapting to the needs of a post-pandemic society.

John D. Macomber is a senior lecturer at Harvard Business School and co-author of a recent book titled *Healthy Buildings: How Indoor Spaces Drive Performance and Productivity*. In an article, he said that “savvy business leaders and landlords will begin to leverage healthier indoor spaces as recruitment tools and sources of competitive advantage. Anxieties over COVID-19 are likely to accelerate these trends”. Macomber believes there will be less demand for office space, and “offices with the premier health story will get the premium rent and get the tenants”.

How a sick building affects well-being

An unhealthy building harms employee well-being in various ways as a result of poor indoor air quality, contaminants, noise levels, poor lighting and inadequate ventilation. These conditions – if not monitored and controlled – can lead to respiratory and cardiovascular illness, anxiety, depression, discomfort and decreased job satisfaction. The World Health Organisation estimates that indoor air pollution causes 11 per cent of COPD (chronic obstructive pulmonary disease) deaths worldwide.

Well-being issues in unhealthy buildings include:

- **Exposure to indoor air pollution:** Leading to respiratory damage and pulmonary impairment
- **Building materials with chemical toxicants:** Harming respiratory, endocrine and neurological systems
- **Insufficient or improper lighting:** Causing discomfort, diminished job performance and lower job satisfaction
- **Poor ventilation:** Leading to short-term illness (coughing, sneezing, fatigue) and serious health problems (lung cancer, asthma, allergies)

When seeking to improve well-being, building developers, owners and city leaders should be concerned with more than just new buildings. Because an estimated 70 per cent of buildings that will be in use in 2050 have already been built, concentrating on new construction projects will have only marginal effects on improving well-being. Therefore, renovation of existing buildings offers significant opportunities.

Prescriptions for smarter, healthier buildings

Thanks to a scientific knowledge base, organisations are more aware of the relationship between the indoor work environment and employee health. Two areas where smart building stakeholders can take action to enhance well-being are monitoring and controlling the indoor environment to reduce health risks and designing the workspace to make it more conducive to job performance and employee comfort.

Monitoring and controlling the indoor environment

Research confirms that indoor air quality (IAQ) affects the well-being of building occupants and that poor IAQ is linked to lower productivity levels and sick building syndrome – a medical condition where people suffer from illness symptoms for no identifiable reason. The World Health Organisation believes that improving IAQ is one of the most important actions society can take in the building industry.





Unhealthy conditions cause unhealthy indoor air

Many unhealthy conditions in buildings contribute to poor air quality. Consider three of the main culprits:

- Carbon dioxide (CO₂)
- Volatile organic compounds
- Particulate matter

A high level of CO₂ is correlated with sick building syndrome and its impact on employee health. Exposure to excessive CO₂ levels leaves an employee feeling dizzy, faint or uncomfortable, reduces job performance and contributes to absenteeism and presenteeism. A study on indoor environments funded by facilities management company EMCOR UK confirmed that worker performance declines when carbon dioxide exceeds acceptable levels.

Volatile organic compounds (VOCs), emitted in buildings through adhesives, paint and solvents, cause eye and throat irritation, nausea, headaches and more serious problems including cancer and damage to the nervous system. VOCs are found in concentrations two to five times greater in indoor environments than in nature.

Particulate matter is defined by the U.S. Environmental Protection Agency (EPA) as a complex mixture of small particles and liquid droplets. The size of particles is directly linked to health risks, and very small particles which enter the lungs can cause serious illness. The EPA says controlling indoor air quality involves managing the source of pollutants, diluting pollutants, removing pollutants from the building through ventilation and using filtration to cleanse the air.

Using a connected lighting system to monitor and control indoor conditions

A connected lighting system can serve as a platform to host sensors and enable facility managers to leverage the value of a building's lighting infrastructure by monitoring workspace parameters such as occupancy, temperature, light, noise, air quality, relative humidity, volatile organic compounds, CO₂ levels, dust and pollution. These capabilities enable businesses to monitor the office environment and optimise conditions for the well-being of employees and visitors.

Human-centric design and well-being

Research reveals that empowered offices – in which workers choose their preferred workspace conditions – “can increase productivity on cognitive tasks by 25 per cent or more”. One of the most innovative ways to provide an empowered office and a human-centric approach to employee well-being is through a building's lighting infrastructure.

The objective of a traditional lighting system is to provide visual indoor conditions for employees to work comfortably and complete their tasks safely and productively. However, a traditional lighting system, designed for the average occupant, does not recognise individual needs. A connected human-centric lighting (HCL) system, on the other hand, increases well-being by allowing employees to control light intensity, colour and spatial brightness in their workspaces and in other areas of the building. The well-being benefits include “brighter moods, sharper focus and heightened alertness. Soft, dim light helps spur creativity, while brighter lights can help our mood and ability to focus”.

Jonathan Weinert, an IoT lighting thought leader at Signify, explains the difference between a connected versus networked lighting system: “Connected lighting and networked lighting are not synonymous. The ‘connected’ part of connected lighting means lighting with two-way data communications embedded in it. In other words, connected luminaires can both receive data (lighting control commands) and share data (system operational data and/or sensor data, which gets transmitted to a data repository, usually in the cloud). This two-way distinction is important, because there are networked lighting systems that send data only one way – down to the luminaires, for software-based lighting control”.

“Evidence is growing that light doesn’t just help us see. It impacts how we feel and behave,” writes Peter Duine, Signify global product manager, on the company’s website. Duine explains that human-centric lighting (HCL) applies the power of light “to improve how we live and work. By tuning light to support our circadian rhythms and emotional needs, we can promote human comfort, well-being and performance”.

Workspace management is another smart building challenge where a connected lighting system delivers innovative solutions. Facilities managers are often confronted with the issue that up to 50 per cent of office space is under-utilised. A connected IoT-based lighting solution with people-counting sensors and space management software enables facility managers to analyse occupancy data and create workspace solutions that enhance space utilisation and employee satisfaction.

As workspace design evolves – from widely used open-plan environments and activity-based working – toward a workplace experience model, organisations are concerned with how to enhance employee performance, productivity, comfort and collaboration. This means creating workplace environments with flexibility for an employee to choose a temporary workstation, communal space to engage with co-workers or a private space to focus on a creative task. With this design strategy, employees have more control of their office





environment and freedom to choose the workspace they feel is most suitable. Implementing the strategy requires indoor navigation tools to support productivity and engagement through wayfinding and location-based services. Organisations can leverage the connected lighting infrastructure and real-time occupancy data to guide employees and visitors within the building.

Coronavirus risks — and the imperative for social distancing measures — add a workplace safety dimension to indoor navigation. Occupancy sensors can help companies ensure post-pandemic safety by spacing employees appropriately and directing them to areas with less activity.

By transforming the lighting system from an in-building utility to a connected, human-centric asset — enabling increased well-being, job satisfaction and productivity — companies and public sector organisations add significant value to smart buildings.

“Light doesn’t just help us see. It impacts how we feel and behave”

Circadian lighting: A major step toward enhanced well-being

Scientists and health experts tell us that we all have an internal clock – known as circadian rhythm — that operates on an approximate 24-hour cycle. This natural process affects our energy and alertness and may cause variations in the cognitive skills we need to complete tasks. Circadian rhythm disorders can lead to daytime drowsiness, irritability, decreased alertness and poor job performance.

In recent years, researchers revealed the potential benefits of indoor lighting solutions that support the human circadian rhythm. Such solutions strive to mimic the behaviour of the sun in indoor situations. The goal is to create a more comfortable environment and increase employee job performance and productivity.

Mauricio Rossi, from the Polytechnic Institute of Milan and author of *Circadian Lighting Design in the LED Era*, said in an interview that our general health depends on the circadian rhythm and “people who have difficulty regulating their circadian rhythms are more likely to develop a wide range of illnesses”. Through awareness of the relationship between light and human circadian rhythms, lighting providers can take major strides in developing new well-being solutions. Bio-adaptive lighting recreates the natural light curve and follows the body’s natural circadian rhythm throughout the workday. Organisations can promote concentration and collaboration via bio-adaptive lighting options to support favourable outcomes, such as enhanced alertness after the lunch hour.

Regarding the adoption of circadian lighting, Dr. Mariana Figueiro, director of the Lighting Research Centre (LRC) at Rensselaer Polytechnic Institute, told *Smart Cities World*: “I think initial cost is still a barrier, but there is a misconception that circadian lighting needs to be tuneable. Dimmable lighting only would work too, but no one is thinking about that”. Figueiro believes another issue is the lack of appropriate measurements. “There are a few places where people have claimed to install circadian lighting solutions, but the biggest issue is that no one is properly measuring these installations to assure the delivery of appropriate lighting conditions. Just because it is tuneable lighting (which a lot of places now have) does not mean it is circadian lighting.” Figueiro says a recently released UL guideline for promoting circadian light should be a “first step to increase adoption and help people implement this technology correctly”.





MIT and Signify in research partnership

In 2015, Signify announced a \$25 million commitment to an R&D alliance with the Massachusetts Institute of Technology (MIT) aimed at developing innovative solutions for challenges in wellness, healthcare and connected lighting systems. This collaboration explores advanced lighting systems and services. In the Mindful Photons project at MIT, researchers seek to improve communications with artificial lighting systems. "Despite the significance of light in structuring human relationships with their environments, we communicate very little with our artificial lighting systems," writes Nan Zhao, a project researcher at MIT. Zhao says advanced sensing technology enables better communications and offers opportunities for context-aware services. When exploring context-aware lighting, researchers identify the need for preferred lighting in diverse situations such as reading printed material, brainstorming in a group, using a laptop or having a private video conference.

Designing smart buildings to protect against contagious disease

Perhaps in the near future, well-being will depend on how building occupants are protected against the spread of contagious disease. University researchers claim that a low dose of ultraviolet (UV) light efficiently inactivates airborne aerosolised viruses. The South China Morning Post reports this application of UV light is being used successfully to disinfect interior surfaces in public transport vehicles in Shanghai.

The LRC at Rensselaer Polytechnic is investigating a hybrid UV lighting system offering no-touch disinfectant methods to reduce hospital-associated infections. This involves the use of short-wavelength light, ranging from ultraviolet to blue light. According to their research, short wavelengths can deactivate pathogens, with varying effectiveness based on wavelength, duration, and amount of light. Signify has ramped up production of its portfolio of Philips UV-C lamps and Once BioShift chambers, and is developing sensor-enabled air disinfection and surface disinfection systems for multiple applications where they can have a positive impact.

Well-being standards

Smart building stakeholders can benefit by developing well-being best practices based on industry standards and emerging guidelines.

The International WELL Building Institute (IWBI) provides the WELL Building Standard which defines lighting design categories for well-being and includes guidelines on glare reduction, brightness levels, colour quality and lighting patterns to support circadian rhythm.

Fitwel is a building certification program designed to encourage widespread adoption of health-promoting measures for the building industry. The Fitwel Standard provides tailored scorecards for existing and new buildings.

BREEAM is the leading sustainability assessment method for buildings and infrastructure. BREEAM's objective is to ensure performance improvement and innovation by providing third-party assessments and certification of buildings.

Case study:

Atea – A Smart Living Lab

Atea, a leader in IT and system integration in the Nordic and Baltic countries, decided to build a smart building in Stavanger, Norway. As part of its strategy to move beyond the traditional IT services market – and offer smart building solutions – Atea designed its smart building as a living lab. The vision was to create a smart building that serves as a test bed and showcase for the connected and integrated systems they plan to develop for smart cities.

“By saying that this building is a living lab, we’re thinking of it as a place where we do our proof of concepts,” says Espen Riska, smart buildings director at Atea. In the living lab, Atea is constantly evolving while using and testing their products and partners’ products.

“As a smart office solution showcase, the new building allows Atea to demonstrate to customers what they can do with a converged infrastructure.” Because the building also houses Atea’s Stavanger workforce, the company has two equally important objectives – ensuring employee well-being and showcasing smart solutions. Riska says that smart technology can be embedded into an office environment in a way that supports both employee well-being and operational efficiency only if planned from the earliest stages of design and development.

To implement the smart building and living lab vision, Atea worked with technology partners Cisco and Signify to develop a converged system for lighting, WiFi, employee well-being and facilities management. Signify installed 500 luminaires throughout the new building. Cisco’s Power-over-Ethernet infrastructure sends both data and low-voltage electricity over standard Ethernet cables, powering the luminaires without the need for electrical wiring. Data received from the luminaires and sensors embedded in the lighting system are received by an IoT platform that is part of the Interact Office IoT lighting system from Signify. Data on light levels and occupancy are used to monitor energy use and faults, analyse building use and improve space allocation.

“The Interact Office solution from Signify is based on open APIs. This means the solution integrates with Microsoft Exchange and Active Directory and integrates with meeting rooms, users, calendars and other resources in the building,” says Riska. By using the Interact Personal Control App (PCA), Atea employees locate available workstations, control temperature and lighting in their workspace and search for vacant conference rooms. Employees can personalise the lighting and temperature with the PCA connected to WiFi.

Atea recognised the need for proper lighting to support the body’s natural circadian rhythm. A glass-roofed atrium provides natural light and features a bio-adaptive lighting application that uses LED luminaires together with Interact Office software to reinforce circadian health. The Interact Office bio-adaptive lighting solution automatically changes intensity and colour temperature depending on the time of the day – brighter, bluer light in the morning; softer, redder light later in the afternoon.





Case study:

TU Eindhoven ATLAS – A Smart, Sustainable Model

TU Eindhoven, the city's university of technology, transformed its outdated main building into a sustainable and future-proof educational building. "Partly thanks to Interact Office, a connected lighting system, TU Eindhoven now has an iconic building," which allows 4,000+ occupants to use a smartphone app to control the light intensity in their workspace. This increases employee well-being, empowerment and comfort.

The TU Eindhoven smart building system consists of 4,400 connected LED luminaires with a sensor slot. Each luminaire acts as an Ethernet data point. This approach offers building managers a new perspective on management and control through the power of IoT technology whereby sensors provide a wealth of data about the building and how it is used by occupants. Using visible light communication (VLC), each luminaire transmits a unique identifier via LED light beams. This identifier is detected by the camera on a smartphone or tablet. With a specially designed smartphone app, an employee registers his or her location by aiming their mobile device at the light. Then the employee uses the app to adjust the intensity of the light in that specific location (e.g. above a particular desk or workspace). Through the use of data analytics, building managers can develop and maintain a knowledge base on occupant preferences concerning workspace comfort, space management and indoor navigation.

Atlas performs an important role for the TU Eindhoven Intelligent Lighting Institute (ILI), which intends to conduct research on human-centric lighting and the effects of lighting on human performance in this new building. The ILI explores intelligent lighting solutions that "are within reach as a result of the large-scale introduction of advanced LED technologies" and the Atlas network of sensors offers a wide range of options for research and experimentation.



Key takeaways

- For smart building stakeholders and smart city leaders, there is growing awareness of the importance of employee well-being and how buildings affect well-being and health.
- The benefits of well-being investments in buildings include improved indoor air quality (IAQ); better health with less absenteeism and presenteeism; and higher levels of employee empowerment, job satisfaction and productivity.
- Another key benefit of well-being investments – enhanced space management and indoor navigation – can help protect building occupants in the post-pandemic era.
- Technologies such as the IoT, tuneable LEDs, sensor platforms and advanced wireless networks offer opportunities to enhance well-being.
- A building's IoT-enabled connected lighting infrastructure can be used as a resource for design of flexible well-being solutions extending beyond traditional lighting functionality and serving as an integrated system for environmental monitoring, employee comfort and empowerment.
- Research and innovation in lighting offers potential new solutions in circadian lighting and context-aware lighting – leading to improvement in employee performance, concentration and collaboration.



Conclusions

Designing for well-being in buildings is relatively new and complex, due to the multi-dimensional responsibilities covering lighting, IT, IoT systems and sensors, environmental monitoring and controls, workspace design, indoor navigation tools and facilities management.

A future with enhanced human-centric design and well-being for the indoor environment yields opportunities for corporate real estate directors and city leaders to improve well-being and safeguard employee health in commercial and municipal buildings. In addition to designing for well-being in government-owned buildings, smart city leaders should take steps to ensure well-being in commercial buildings by:

- Promoting innovation in air quality and environmental monitoring and implementing regulations that include rigorous inclusion of health criteria
- Facilitating well-being measures and benefits from connected lighting systems and bio-adaptive lighting
- Prioritising well-being enhancements in buildings used by vulnerable citizens (children, elderly, disabled, homeless)

The world will build 230 billion square metres of new construction during the next 40 years (based on a UN forecast) – adding “the equivalent of the city of Paris to the planet every week” and underscoring the need for smart city leaders to take action now in the form of well-being strategies and human-centric policies for real estate development. For architects, building developers and other stakeholders, the lighting infrastructure offers opportunities to develop innovative well-being solutions.

